Description

The invention relates to a method for controlling and protecting a transport system in which vehicles circulate according to a timetable in a network of routes. The method according to the invention can be applied particularly advantageously in transport systems which have a complex network structure and in which there is provision for certain journeys to have priority over other journeys. Railways are an example of such a transport system. However, the method according to the invention can also be applied in shipping or air transport.

When timetables are created, scheduled paths are defined for the vehicles circulating in the network. A path is a travel/time diagram which is obtained from plotting the location of the vehicle against the time axis. A path assigns not only a route but also speeds and accelerations to a vehicle. Consequently, a timetable of a vehicle is composed of its path and a number of items of information which are characteristic for the vehicle, for example the length of the vehicle or a weighting which is assigned to the vehicle in accordance with commercial criteria. The timetable of part of a network is a spatial excerpt of the timetables of all the vehicles which circulate in this part of the network. The term timetable is used below in the sense of the timetable of the entire network or of parts of the network.

A publication by O. Brünger entitled "Konzeption einer Rechnerunterstützung für die Feinkonstruktion von Eisenbahnfahrplänen" [Scheme for providing computer-support for the detailed structuring of railway timetables], Veröffentlichungen des Verkehrswissenschaftlichen Instituts der Rheinisch-Westfälischen

Technischen Hochschule Aachen [publications of the Transport Institute of the Technical University of North Rhine-Westphalia, Aachen], issue 51, 1995, discloses a method for the computer-supported generation of railway timetables. In this known method, the infrastructure of the railway network (including tracks, railway switches, gradients, permissible speeds, signals, tunnels) is mapped as a node-evaluated, directional graph. The infrastructure also comprises the position and length of the occupation elements. These are track sections of a specific length whose occupation is monitored by signaling equipment. The occupation times of the individual occupation elements can be calculated on the basis of this graph by calculating the travel times, and conflicts between paths which are provided can be identified in spatial and chronological terms taking into account dependencies between signaling equipment. If conflicts occur, the originally predefined desired paths are changed until a conflict-free timetable is obtained. When this change to the paths occurs, trains with a high priority are handled with preference. They then obtain paths whose travel time is near to the minimum conveying time valid for the given route.

The manual entry of timetable paths into travel/time diagrams, which was previously customary and during which the generation of conflicts could be estimated only in an imprecise way, is eliminated when this known method is used. Other transport networks, for example in shipping or in air transport, can be mapped in a similar way, with the result that the application of this method is not restricted to the generation of railway timetables.

If disruptions occur during the operation of the transport system, delays and thus deviations from the timetable occur. In this case, it is no longer ensured that the rest of the operation will run without

conflict. Although collisions between vehicles do not generally occur then - these are prevented by existing safety systems - it is, however, possible for disruptions in the operational flow to occur which adversely affect the quality of the transport services on offer. In particular in railway networks with their restricted overtaking possibilities, delays very quickly affect other trains. When there are disruptions in the operational sequence, a deployment official therefore attempts to create a modified timetable ad hoc for the affected network section, taking into account the types of train. This modified timetable is intended to keep deviations from the intended timetable as small as possible for high-priority trains. When this change to the timetable occurs, the deployment officer is in particular reliant on his experience and on the manual timetable-generation method referred to above. However, with this method conflicts can only be avoided locally and to a limited extent in terms of time. Owing to the complexity of the operation, the deployment officer can only make a rough estimation of what effects the changes which he makes will have on the rest of the operation, especially at more remote locations.

The object of the invention is therefore to specify a method for controlling and protecting a transport system, in particular of railways, in which the operational disruptions have as little effect as possible on the quality of the transport.

According to the invention, steps specified in claim 1 are provided to achieve this object. A data processing system calculates a new timetable during ongoing operation. Such a calculation can be carried out continuously or at short regular time intervals. However, the new timetable is preferably not calculated until the operation of the vehicles deviates from the timetable by more than a predefined degree. It is

essential to the invention that this new timetable should not contain any conflicts, that is to say that the vehicles do not occupy the same occupation element at any time during the operation. After the new timetable has been generated, the control and protection of the transport system is carried out directly in accordance with this new conflict-free timetable. In comparison with the ad hoc method previously carried out by a deployment officer, application of the method according to the invention provides in particular the following advantages:

- The new timetable can be generated in a very short time using a personal computer. There are virtually no delays in the transport operation owing to reorganization of paths. There is no need for mainframe computers.
- The new timetable is guaranteed to be conflict-free. The transport in the network can be executed in accordance with this new timetable without conflicts occurring which make renewed reorganization of paths necessary. Because conflicts are ruled out from the outset, applying the method according to the invention even makes it possible to largely dispense with the previous safety systems. If the data processing system which generates the timetable is informed of the location and speeds of the vehicles, it controls the vehicle directly. In the case of railways, for example, the data processing system then forms the routes directly, i.e. without the intervention of control boxes. The locomotives receive information on the path provided for them from the data processing system by radio and can thus appropriately control their speed. Deviations from the new timetable are then necessary only if there are more unexpected operational disruptions which make further revision of the timetable necessary. This revised timetable then replaces the timetable which was valid until then.

The explanation is explained in detail below with reference to the drawings. The described exemplary embodiments relate primarily to railways. However, as mentioned above, the method according to the invention is not restricted to railways. In the drawings:

Fig. 1 shows a schematic representation of a part of a network of rail lines,

Fig. 2 shows a flowchart of the method according to the invention as claimed in claim 2,

Fig. 3 shows an excerpt from a flowchart for the method according to the invention as claimed in claim 3,

Fig. 4 shows a representation of a timetable for a section of a railway route with fixed occupation elements in which the train path and the associated blocking time step are plotted on a travel/time diagram,

Fig. 5 shows a representation, corresponding to fig. 4, of a timetable for a section of a railway route which is operated using the moving block method.

The part of the network NETWORK shown in fig. 2 is composed of the stations BF1, ...BF6, the junction station BFK and rail routes which connect these to one another. The links are embodied in this example as single-track, two-track, three-track and four-track routes. In the region of the single-track route between the stations BF1 and BFK there is an overtaking station OST. The junction station BFK contains route junctions FSK1 and FSK2 at which routes coming from a plurality of stations join. Route nodes are generally points in the route network which are susceptible to conflict because the train density is particularly high at them.

Trains - not illustrated in fig. 1 - circulate on the part of the network NETWORK according to a timetable. This timetable is preferably generated using the method known in the publication cited at the beginning, and is

thus conflict-free. A timetable is referred to as conflict-free in this context if the possibility is excluded that two trains could come so near to one another that under the given circumstances (braking distances etc.) there could be a collision between the two trains. In modern route networks, the routes are divided up into fixed occupation elements which are protected by signaling equipment.

Conflict-free then means that two trains do not occupy the same occupation element at any time.

During the generation of the timetable, the distances between trains are specified in such a way that if a train deviates slightly from the timetable the operation of the other trains is not adversely affected. However, if the deviation from the timetable exceeds a certain degree, other trains may be affected by this deviation and conflicts may arise. This is explained below by means of a simple example. Between the stations BF2 and BFK, a slow train is to allow a faster train which is traveling in the same direction to overtake at the overtaking station OST. If the slow train does not reach the overtaking station OST at the right time owing to an operational disruption, for example owing to a defect in the locomotive of the slow train, the following faster train must reduce its speed in order to avoid a rear-end collision with the slow train. The faster train then reaches the junction station BFK later than foreseen. However, it has then possibly missed the time window which was assigned to it for it to pass through the route junction FSK1 according to the timetable. If there is heavy traffic on the route junction FSK1, it is necessary to allow for the fact that a further train, coming from the station BF4 for example, may wish to enter the route junction FSK1 at the same time as the delayed arrival of the faster train. There is therefore a conflict.

Steps according to which such a problem is handled in the method 10 according to the invention are illustrated in the form of a flowchart in fig. 2. During ongoing operation 11, the operation of the trains is monitored continuously or at short time intervals to determine whether it deviates from the timetable by more than a predefined degree (step 12). This degree depends, inter alia, on the tolerances provided in the blocking times (see below for more details). Timetable deviations can be determined in different ways. For example, the locomotives themselves can compare their actual operation with the scheduled operation according to the timetable and, in the event of a deviation, report this to a central data processing system, for example by radio. It is also possible for the locomotives to report their location and their speed to the central data processing system by radio and for said system to carry out the comparison with the scheduled values in the timetable.

If a deviation which is detected from the timetable exceeds a predefinable degree, according to the invention a new conflict-free timetable is calculated in a step 13 on the basis of the momentary operating situation. The calculation is basically carried out in the same way as when the original conflict-free timetable was generated. However, in contrast to the original timetable, the new timetable is generated automatically, i.e. without the intervention of a deployment officer. As a result, the necessary short reaction times can be maintained. It may, under certain circumstances, be appropriate to calculate only part of the timetable for part of the network and for a specific deployment time period.

After the calculations are terminated, in step 14 the previous timetable is replaced by the new timetable. If the new timetable is valid for only part of a network or for a specific deployment time period, only the

respective parts of the existing timetable are replaced. The further operation of the transport system is carried out in accordance with this new timetable from this time onward.

Alternatively, it is possible to carry out the calculation 13 of a new timetable continuously or at short regular time intervals. The calculation is then no longer triggered by the result of the check as to whether the operation of the trains deviates from the timetable by more than a predefined degree. In this case, it is therefore possible to dispense with the step 12. If no operational disruptions have occurred since the last calculation of the timetable, the newly calculated timetable will fit with the old timetable. In order to avoid an unnecessarily large flow of information between the data processing system and the trains, it is, however, expedient to carry out a comparison of the timetables in the data processing system itself. Information on the trains' schedules according to the new timetable then has to be transmitted to the trains only if there are deviations between the new timetable and the old timetable. Because, in this alternative exemplary embodiment, the comparison between the scheduled route and the actual route of the trains is ultimately only replaced by a comparison between the old timetable and the new timetable, there are no actual advantages over the method described above.

Then, the principles according to which a new conflict-free timetable can be calculated are explained by reference to figs 3 and 4. Details on this can be taken from the publication cited at the beginning. Fig. 4 shows a direction of travel of a two-track railway route EST which is divided into a plurality of occupation elements by signals S1...S7. The occupation elements are identical in the conventional signal system which is illustrated in fig. 4 with blocks, and

they therefore have a fixed length and position. An overtaking possibility OP is provided by means of two railway switches W1 and W2. A time axis is shown perpendicular to the railway route EST so that a travel/time diagram is produced. The travel of a train is illustrated in this diagram as a continuous line ("path"). In the illustrated example, a relatively slow train Z1 travels over the route EST and is directed to the overtaking track OP. It remains there in order to allow a second, faster train Z2 to pass by. The travel of the slower train Z1 is illustrated by the path TR1, and that of the faster train Z2 by the path TR2. The hatched regions indicate how long the occupation elements were occupied by the two trains Z1 and Z2. These occupation times are designated as blocking times. The length of the blocking times depends, inter alia, on features of the trains (speed, length, braking capacity etc.) as well as the type of the occupation element (railway switch, free route). The sequence of blocking times results in a set of blocking time steps. The set of blocking time steps SZT1 is assigned to the slow train Z1 and the set of blocking time steps SZT2 is assigned to the faster train Z2. OS characterizes the occupation of the overtaking track OP by the slower train Z1. This occupation OS restricts the travel of the faster train Z2 on the through-route EST.

As shown in fig. 3, according to the invention the network is divided into suitable occupation elements in a step 131 for calculating a new timetable. The occupation elements may already be predefined by means of existing blocks which are protected by signaling equipment. It is also possible to perform a virtual subdivision, which does not fit with a block structure which may be present. This division can in principle be carried out in any desired way and in extreme cases it can tend toward zero, which corresponds to driving according to the principle of the moving block. Then, in a further step 132, the sets of blocking time steps

for the occupation elements are determined for the paths which are provided. In a method according to the invention, a tolerance to cover the permitted degree of deviation from the timetable is added to the blocking times. The finer the division of the network into occupation sections, the more the sets of block time steps approximate to the bands of blocking times. In contrast to fig. 4, in the route section shown in fig. 5 the occupation elements are infinitesimally small so that the occupation times are presented here by blocking time bands SZB1 and SZB2. Edges in the blocking time bands are due to the fact that the route is not continuous at individual points - as in the region of the railway switches W1 and W2 here - but instead can only be occupied or released on a section-by-section basis.

After the calculation of the sets of blocking time steps or bands, in a step 133 it is determined whether, and if so where and at what time, conflicts occur. In the representation of the sets of blocking time steps, a conflict is easily detected at the overlap between two sets of blocking time steps in the region of the same occupation element. Finally, in a step 134, if conflicts have been detected the train paths and thus the sets of blocking time steps are modified, displaced or re-ordered in such a way that an overlap of the sets of blocking time steps does not occur in the travel/time diagram. The timetable is then conflict-free. It is possible to take into account, inter alia, the hierarchy of trains, possible delays which have occurred up to the generation time and predefined values by a deployment officer or deployment algorithm in the change to the paths which have been adopted until then. High-ranking trains and trains with a long delay are generally assigned to paths which permit the shortest possible travel time. Further influencing variables can also be included in the calculation of the timetable, for example coefficients of friction

which can fluctuate during operation owing to environmental influences (rain, foliage). The ultimate position of the paths defines a new timetable on which further operation is based.

Because not only the original timetable but also the timetable or timetables which are generated after it during the course of operation are conflict-free, there is a priori protection of routes against conflicting travel. Thus, as already mentioned above, it is possible to largely dispense with previous safety equipment. A data processing system which calculates the new timetable can then form the routes itself, that is to say without the interaction of signal boxes. To do this, the data processing system transmits the setting commands directly to the railway switches, for example by radio, and receives the acknowledgement telegrams transmitted by the railway switches. The data processing system allocates the setting command to the start of the blocking time for the respective occupation element. From the data processing system, the locomotives receive information on the path provided for them - possibly a new one - and control their speed correspondingly themselves.

In order to safely control the transport operations, all that then needs to be ensured is that the data processing system is reliably informed of the location and the speed of the trains at all times. A device for precisely determining the location and speed of trains is known, for example, from DE-A1-195 13 244 and is not explained in more detail here for that reason. Methods for safely transmitting data by radio between trains and their operating control boxes are also known, there being no need for a particular reference thereto. In addition, for the safety of operation it is necessary to be able to reliably check the integrity of the trains. Various devices for this are known also, and they do not need to be explained in detail here.

However, the method according to the invention can also be integrated into existing safety concepts. The division of the network into blocks which are protected by signaling equipment and the formation of routes by means of control boxes can be combined with the method according to the invention in that the timetable which is respectively newly calculated by the data processing system is transmitted to the signal boxes. The signal boxes then direct the trains through the network in the previously known way. By making available updated conflict-free timetables, the operational sequence can be made significantly smoother. Because in principle, the operation can be simulated far into the future (as far as desired) when generating timetables, conflicts which also lie chronologically and spatially far ahead can be detected early and avoided. In the example described above with reference to fig. 1, the method according to the invention can be used, for example, to ensure that the higher-priority, faster train receives an optimum path. In this case, the optimum path would be such that the faster train travels past the overtaking station OST at the highest possible speed as soon as the slower train has come to a standstill on the overtaking track and the railway switch has been switched over. Such an optimized deployment of trains cannot be achieved with conventional methods, or can only be achieved unreliably.

Depending on the embodiment of the invention, the data processing system which calculates the new timetable can be a central computer for the entire network, which central computer also performs the checking to determine whether the trains are operating beyond the predefined degree. If appropriate, it may be more favorable to divide the data processing system spatially and functionally into a plurality of sub-computers which communicate with one another. An example of this would be traffic networks which extend over very large areas, for example as in air transport.

However, it is to be noted in particular that the method according to the invention does not in principle require any use of mainframe computing systems or very extensive data storage. Relatively high computing powers are necessary only when very short occupation sections are selected.

If the method is to be applied for other means of transport, modifications are necessary in comparison with the above, but they are not fundamental in nature. In shipping, for example, instead of railway switches there are junctions of rivers or canals at which conflicts can occur. Overtaking operations are not possible everywhere on waterways and must therefore be planned in advance to avoid collisions with oncoming ships. A division into occupation elements and the calculation of sets of blocking time steps are also appropriate and possible here.

Patent claims

1. A method for controlling and protecting a transport system in which vehicles circulate (11 in fig. 2) in a network (NETWORK) of routes, using a data processing system, characterized

   a) in that the data processing system calculates (13) a new conflict-free timetable during ongoing operation of the transport system,

   b) and in that the control and protection of the transport system is carried out according to this new conflict-free timetable (14).

2. The method as claimed in claim 1, in which the data processing system calculates (13) a new conflict-free timetable as soon as the operation of the vehicles deviates (12) from the timetable by more than a predefinable degree.

3. The method as claimed in one of the preceding claims, in which, in order to calculate the conflict-free new timetable, the data processing system

   a) divides (131) the routes of the transport system into occupation elements,

   b) determines (132) the sets of blocking time steps (SZT1, SZT2) or blocking time bands (SZB1, SZB2) of all the occupation elements in a predefined deployment time period on the basis of the current operating situation,

   c) determines, using the sets of blocking time steps or blocking time bands, possible conflicts which could lead (133) to a collision between vehicles,

   d) and determines (134) new conflict-free paths for the vehicles.

4. The method as claimed in claim 3, in which the data processing system determines the new paths taking into account a predefinable hierarchy and possible delays.

5. The method as claimed in one of the preceding claims, in which the data processing system transmits, to the vehicles affected by the determination of the new paths, setpoint acceleration values which correspond to the new paths of these vehicles.

6. The method as claimed in one of the preceding claims, in which the vehicles are rail vehicles and in which the data processing system forms and protects the routes directly, i.e. without the interaction of signal boxes.

7. The method as claimed in one of the preceding claims, in which the rail vehicles determine their position and their speed

a) using track-mounted units and/or a satellite-supported navigation system and/or sensors which measure the rotation of the wheels and/or an inertia navigation system,

b) and signal this information to the data processing system by radio.

Five pages of drawings appended.

Abstract

The invention relates to a method for controlling and protecting a transport system in which vehicles circulate in a network of routes in accordance with a timetable. The intention is that applying the method according to the invention will cause operational disruptions to have as little effect as possible on the quality of the transport.

The invention provides that a data processing system calculates a new conflict-free timetable during ongoing operation of the transport system, specifically preferably as soon as the operation of the vehicles deviates (12) from the timetable by more than a predefinable degree. The control and protection of the transport system is then carried out according to this new conflict-free timetable (14). The calculation of the new conflict-free timetable is then preferably carried out using sets of blocking time steps (SZT1, SZT2) or blocking time bands (SZB1, SZB2).

The method according to the invention can be applied particularly advantageously in transport systems which have a complex network structure and in which there is provision for specific journeys to have priority over other journeys (for example railways).

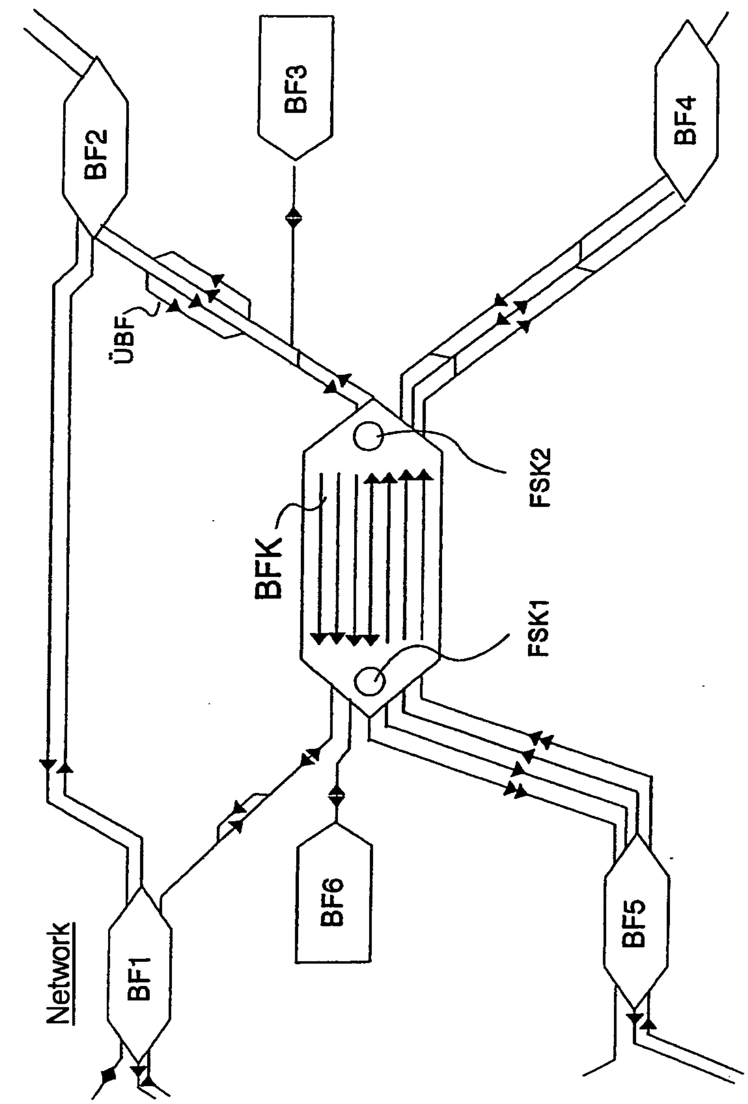


Fig. 1

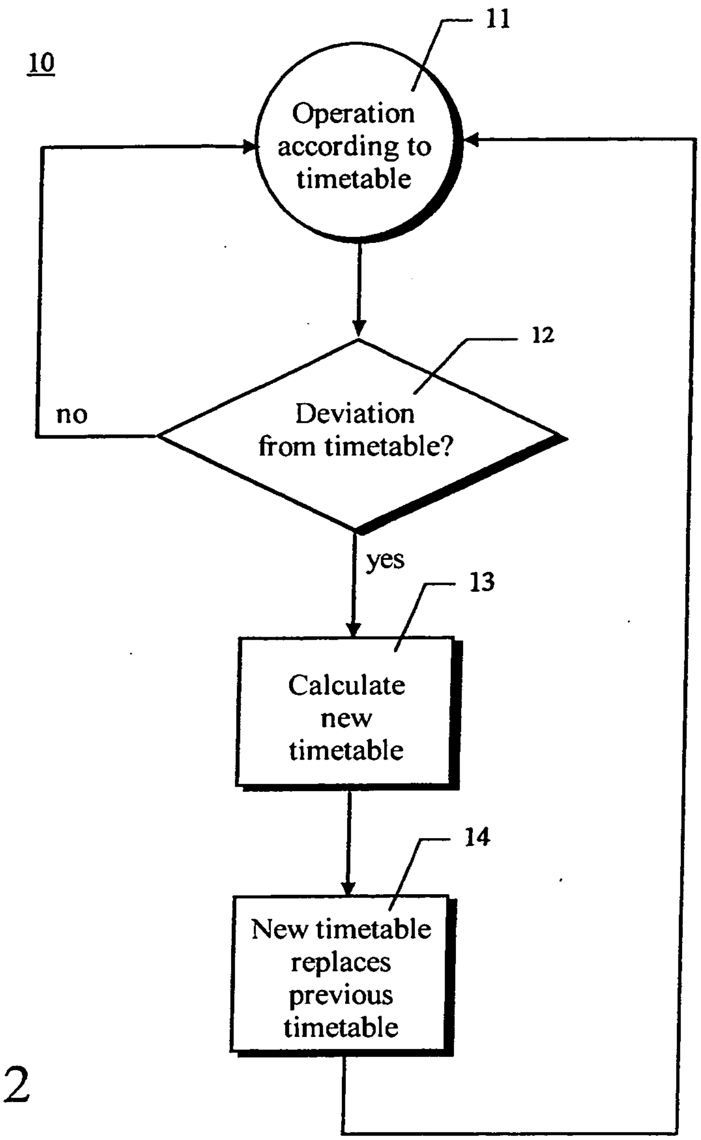

10
11
Operation according to timetable
12
Deviation from timetable?
no
yes
13
Calculate new timetable
14
New timetable replaces previous timetable

Fig. 2

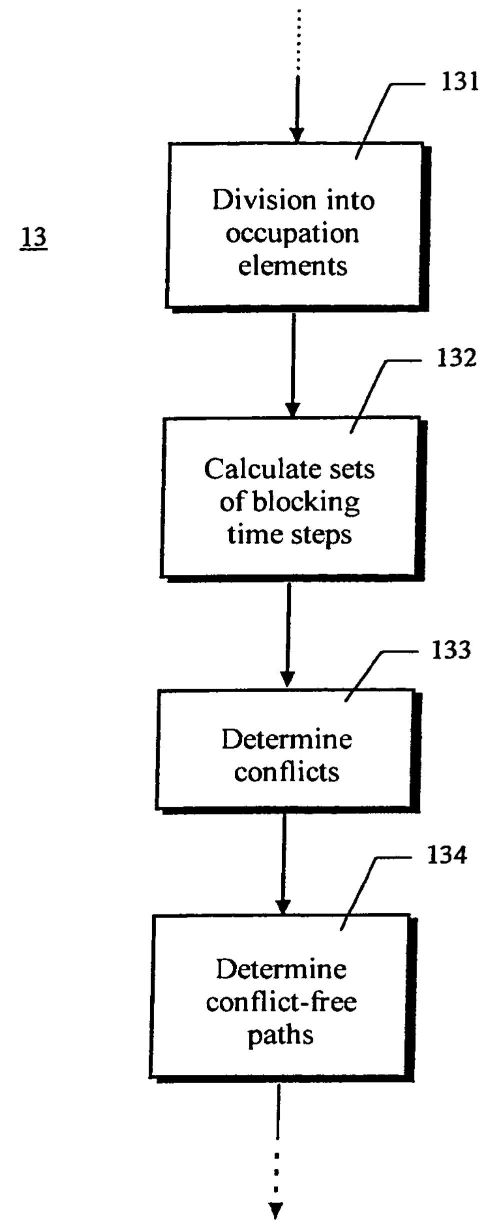
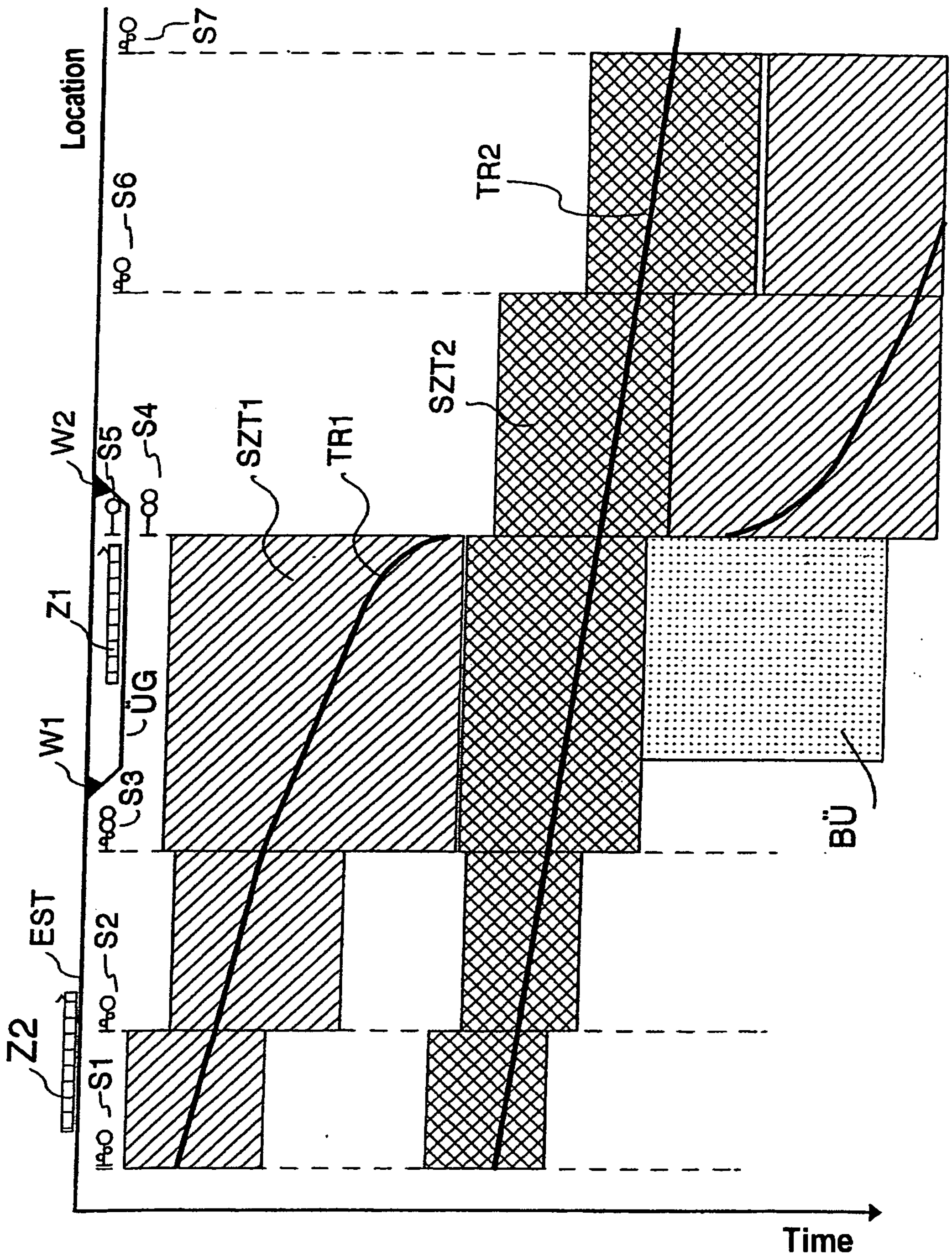

13
131
Division into occupation elements
132
Calculate sets of blocking time steps
133
Determine conflicts
134
Determine conflict-free paths

Fig. 3



Location
Time
S1
S2
S3
S4
S5
S6
S7
W1
W2
Z1
Z2
EST
ÜG
SZT1
SZT2
TR1
TR2
BÜ

Fig. 4

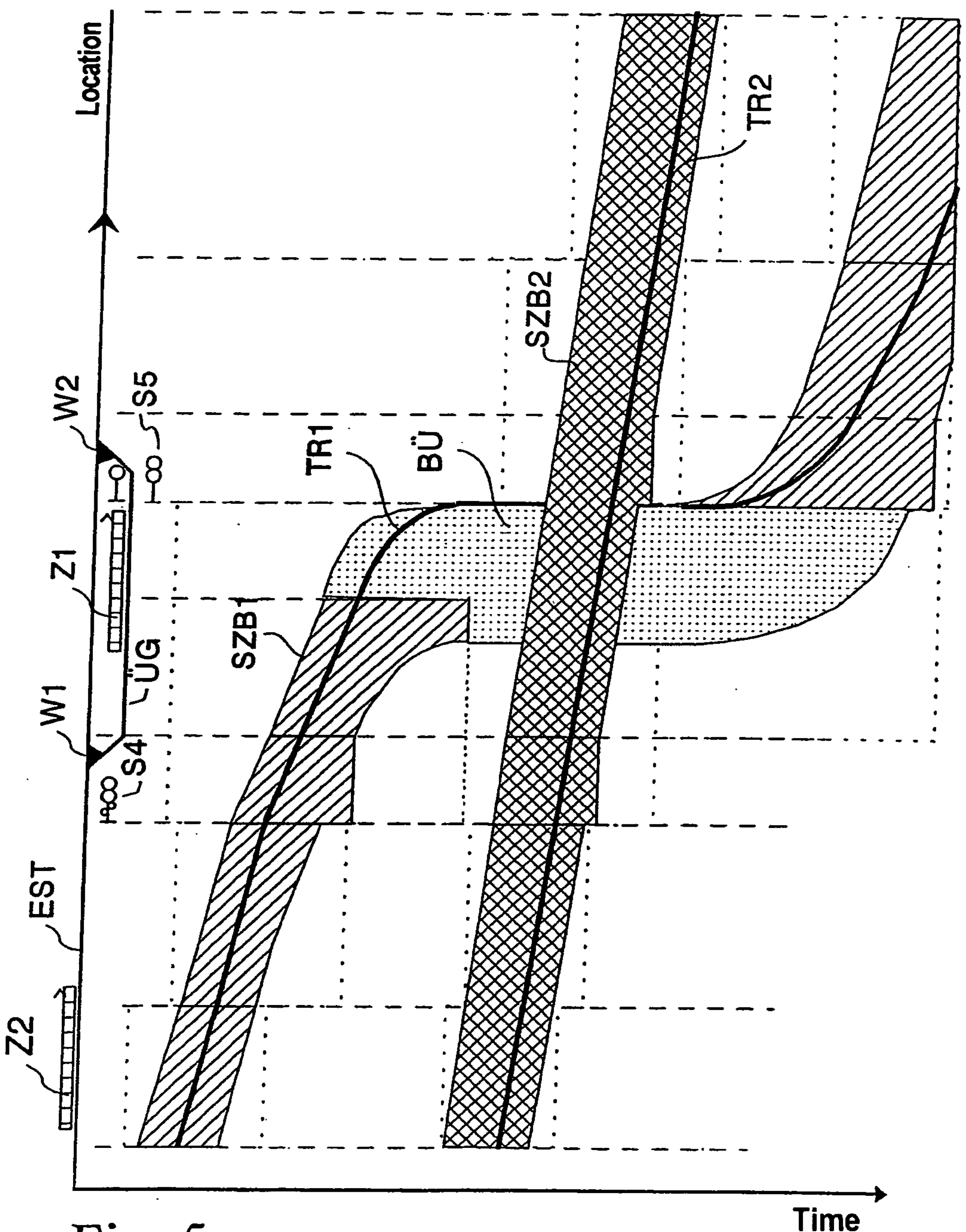


Fig. 5